

Design and Implementation of Fast- Lifting Based Wavelet Transform for Image Compression

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Abstract— The digital data can be compressed and retrieved using Discrete Wavelet Transform (DWT) and Inverse Discrete wavelet Transform (IDWT). The medical images need to be compressed and retrieved without loosing of information. The Discrete Wavelet Transform (DWT) is based on time-scale representation which provides efficient multi-resolution. This paper mainly describes the lifting based scheme gives lossless mode of information. The lifting based DWT and IDWT are having lower computational complexity and reduced memory requirement. Conventional convolution based DWT and IDWT are area and power hungry. These drawbacks can be overcome by using the lifting based scheme. This system adopts lifting based scheme DWT and IDWT which gives the lossless information of the data, reduces the complexity and optimized in area and power. In this research the DWT and IDWT are simulated and the design of hardware model is carried out using RTL level coding.

Keywords- DWT (Discrete Wavelet Transform); IDWT (Inverse Discrete Wavelet Transform); FLA (Fast-Lifting Algorithm); RTL.

I. INTRODUCTION

Wavelets are functions that are concentrated in time as well as in frequency around ascertain point. For practical applications we choose wavelets which correspond to a so called “multi resolution analysis” due to the reversibility and the efficient computation of the appropriate transform. Wavelets fulfill certain self-similarity conditions. Images are obviously two dimensional data. To transform images we can use two dimensional wavelets or apply the one dimensional transform to the rows and columns of the image successively as separable two dimensional transform. In most of the applications, where wavelets are used for image processing and compression, the latter choice is taken, because of the low computational complexity of separable transforms. Before explaining wavelet transforms on images in more detail we have to introduce some notations. We consider an $N \times N$ image as two dimensional pixel arrays with N rows and N columns.

We assume without loss of generality that the equation $N = 2^r$ holds for some positive integer.

II. RELATED RESEARCH

In this paper, they explore the need for an efficient technique for compression of Images ever increasing because the raw images need large amounts of disk space seems to be a big disadvantage during transmission & storage. Even though there are many compression techniques already present a better technique which is faster memory efficient and simple surely suits the requirements of the user. The Lossless method of image compression and decompression using a simple coding technique called Huffman coding [1]. In this paper, they propose the JPEG standard makes use of Discrete Cosine Transform (DCT) for compression. The introduction of the wavelets gave a different dimension to the compression. They aims at the analysis of compression using DCT and Wavelet transform by selecting proper threshold method better result for PSNR have been obtained. Extensive experiment has been carried out to arrive at the conclusion [2]. This work proposes a new image coding algorithm based on a simple architecture that is easy to model and encode the residual samples. In the proposed algorithm each residual sample is separated into three parts: (i) a sign value, (ii) a magnitude value, and (ii) a magnitude level. A tree structure is then used to organize the magnitude levels. By simply coding the tree and other two parts without any complicated modeling and entropy coding good performance can be achieved with very low computational cost in the binary uncoded mode [3]. In this research they propose an approach for lossless image compression in spatial domain for continuous-tone images using a novel concept of image folding. The proposed system uses the property of adjacent neighbor redundancy for prediction. In this method column-folding followed by row folding is applied iteratively on the image till the image size reduces to smaller pre-defined values. For column folding elements of even columns are subtracted from elements of odd-columns. Thereafter row folding is applied on odd-column in a similar fashion. In row-folding even rows are subtracted from odd rows and the resultant odd rows are used for next iteration [4]. In this paper they introduce the study concentrates on the lossless compression of image using approximate matching

technique and run length encoding. The performance of this method can be compared with the available jpeg compression technique over a wide number of images, showing good agreements [5]. In this paper they attempt to give a recipe for selecting one of the popular image compression algorithms based on Wavelet, JPEG/DCT, VQ, and Fractal approaches [6]. The proposed technique produces a bit stream that results in a progressive and ultimately lossless reconstruction of an image similar to what one can obtain with a reversible wavelet codec. In addition the proposed scheme provides near-lossless reconstruction with respect to a given bound after decoding of each layer of the successively refundable bit stream. They formulate the image data compression problem as one of successively refining the probability density function (pdf) estimate of each pixel [7].

III. LIFTING SCHEME

The lifting scheme is an easy tool to construct the second generation wavelets. The scheme consists of three simple stages namely split, predict (P) and update (U). In the split stage the input sequence $x_{j,i}$ is divided into two disjoint set of samples, even indexed samples (even samples) $x_{j,2i}$ and odd indexed samples (odd samples) $x_{j,2i+1}$. In the predict stage, even samples are used to predict the odd samples based on the correlation present in the signal. The difference between the odd samples and the corresponding predicted values are calculated and referred to as detailed or high-pass coefficients, $d_{j-1,i}$. The update stage utilizes the key properties of the coarser signals i.e. they have same average value of the signal. In this stage the coarse or low-pass coefficient $x_{j-1,i}$ can be obtained by updating the even samples with detailed coefficient. The block diagram of the lifting based DWT is shown in Fig-1.

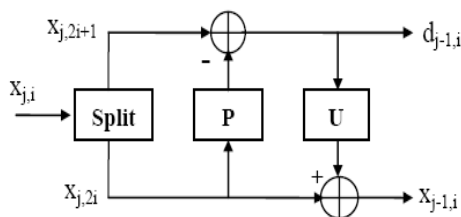


Figure 1. Lifting based forward DWT

IV. METHODOLOGY

Fig-2 shows the steps involved in the design of discrete wavelet transform and Inverse discrete wavelet transform, methods involved in the design and verification of the discrete wavelet transform and Inverse wavelet transform

- Literature reviewed on various Architectures for lossless images using Discrete Wavelet Transform (DWT) and Inverse Discrete Wavelet Transform (IDWT) carried out by referring journals, conference papers, books, websites and related documents
- Design specification of lossless image using Discrete Wavelet Transform and Inverse Discrete Wavelet Transform is formulated based on application and reviewed literature
- Suitable algorithm and architecture for lossless image using Discrete Wavelet Transform and Inverse Discrete Wavelet Transform is identified based on the specifications and reviewed literature

- Sub-modules of the lossless image using Discrete Wavelet Transform (DWT) and Inverse Discrete Wavelet Transform (IDWT) are identified

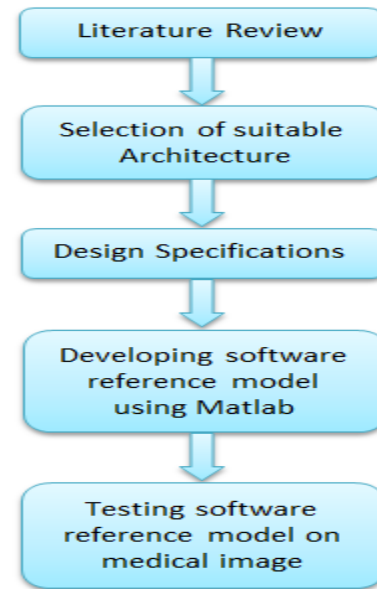


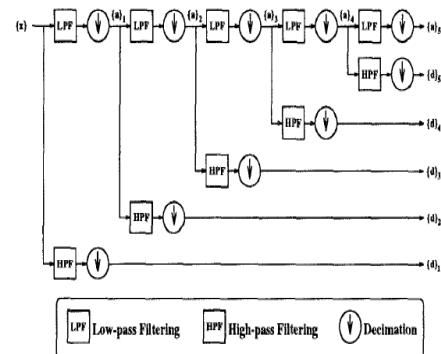
Figure 2. Flow chart of the system

Software modeling for lossless image is developed in MATLAB. Functionality of lossless image using DWT and IDWT are verified against design specifications

V. FILTERING PROCESS

A. Discrete Wavelet Transform

The filtering steps are multiply and accumulate operations. A filter in the algorithmic discrete sense is a number of "coefficient" values. The number of these values referred to as the "filter width" and these coefficients are also referred to as "taps". At each data-word of the input the filter spans across that data-word and its neighboring data-words as a "window". The values within this window are multiplied by their corresponding filter coefficient and all the results are added together to give the filtered result for this data-word. The filtering operation can extract certain frequency information from the data depending on the characteristics of the filter. This filtering operation can be done with a systolic array. It is simple to implement the systolic array for each level of the DWT but the arrays are poorly utilized due to the decreasing data-rates of the levels. It is possible through some complex timing to use a single array to perform all levels of the DWT.



B. Inverse discrete wavelet transform

The inverse DWT (IDWT) is the computational reverse. The lowest low-pass and high-pass data-streams are up-sampled (ie. a zero is placed between each data-word) and then filtered using filters related to the decomposition filters. The two resulting streams can be simply added together to form the low-pass result of the previous level of processing. This can be combined with the high-pass result in a similar fashion to produce further levels the process continuing until the original data-stream is reconstructed.

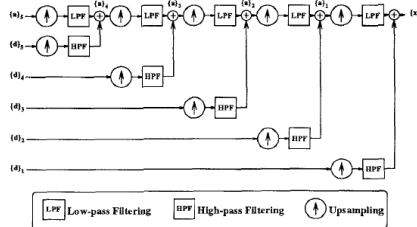


Figure 4. The Inverse DWT filtering process

VI. LEVELS OF DECOMPOSITION

A. Discrete Wavelet Transform of One level DWT:

The DWT is usually computed through convolution and sub-sampling with a couple of filters to produce an approximation signal L (low pass filter result) and a detail signal H (high pass filter result). For 2-D signals, there exist separable wavelets for which the computation can be decomposed into horizontal processing (on the rows) followed by vertical processing (on the columns), using the same 1-D filters.

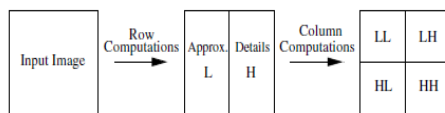


Figure 5. One level separable wavelet decomposition

The multi-resolution DWT and IDWT can be viewed as cascades of several two-channel analysis and synthesis filter banks, respectively. The analysis and synthesis filter banks are shown in fig-6(a) and fig-6(b), where $H(z)$ and $G(z)$ are the analysis low pass and high pass filters. For perfect reconstruction, the synthesis low pass and high pass filters can be defined as $\tilde{H}(z) = G(-z)$ $\tilde{G}(z) = -H(-z)$

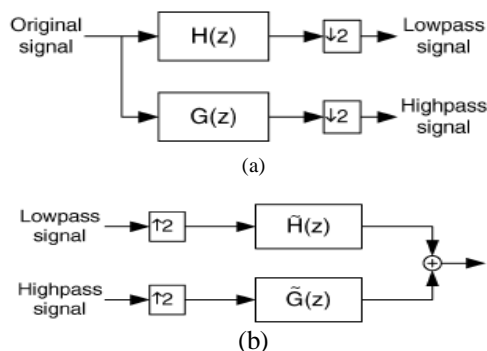


Figure 6. (a) Analysis filter bank for forward DWT. (b) Synthesis filter bank for inverse DWT.

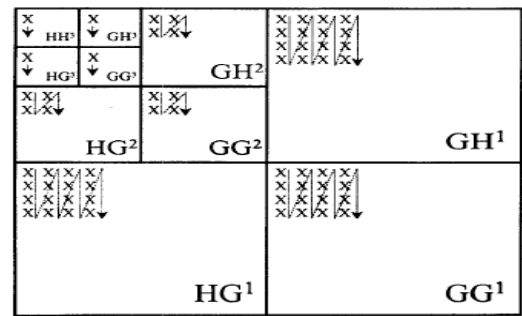


Figure 7. level-3 computation schedule scheme.

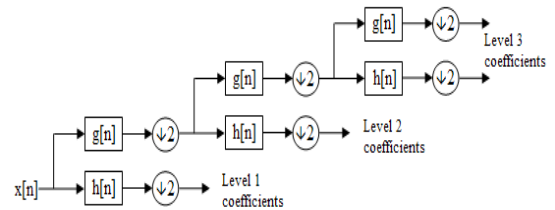


Figure 8. Two channel filter bank at level-3

VII. MATLAB IMPLEMENTATION

Discrete wavelet transform is used for the implementation of the image so that the image was compressed. And the inverse wavelet transform is used to get the original signal. The compression level is 3 levels. Here we used orthogonal filter 5.4. The input image is compressed by levels 3. The below figure shows the compression level

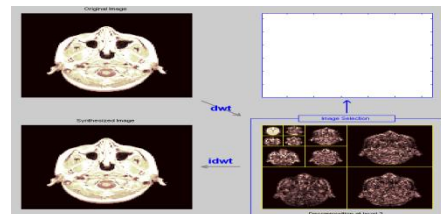


Figure 9. The conversion of the image by using DWT and IDWT

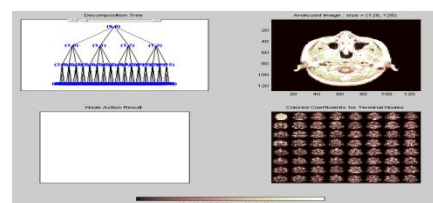


Figure 10. Initial Tree of image

The Fig-10 shows the initial tree of the image. The initial tree divides the input signal into the high pass and low pass signal. The branch of the high pass and low pass again divides high pass and low pass. The sub branch also continues up to the ending of the coefficients.



Figure 11. wavelet tree of image

The fig-11 shows the compression levels of the image. The compression level 3 is used.

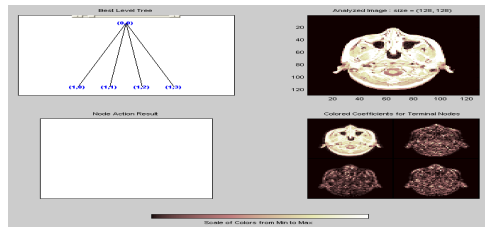


Figure 12. Best level tree of image

The fig-12 shows the best level tree of the image. By using best level we can get at maximum of original image. Here the compression level 1 is used.

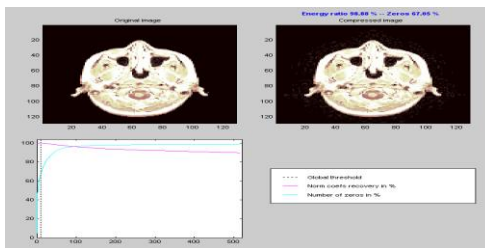


Figure 13. Original and compressed image

The fig-13 shows the original image and the compressed image. The number coefficients recovered is 99.74.

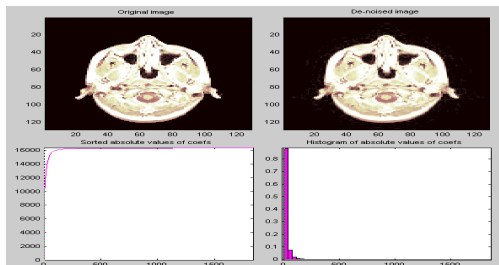


Figure 14. De-noised medical image

The fig-14 shows the original image and the de-noised image. System stores absolute coefficients and histogram of the de-noised image.

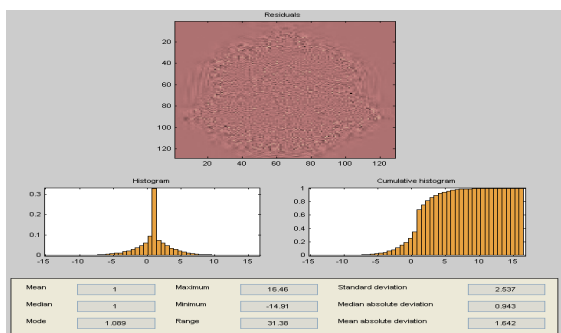


Figure 15. Histogram of the image

The fig-15 shows the histogram of the image. The standard deviation is 2.537, median absolute deviation is 0.943 and the mean absolute deviation is 1.642.

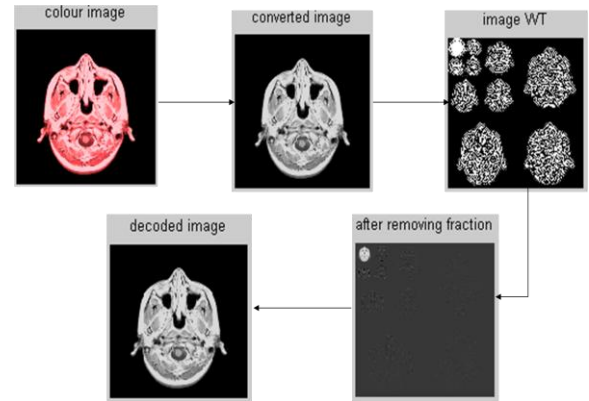


Figure 16. Transmission of image by using DWT and IDWT

The fig-16 shows the conversion of color image into grey scale image.

VIII. EXPERIMENTAL RESULTS OF DWT AND IDWT USING MATLAB IMPLEMENTATION

The testing procedure for DWT and IDWT is as follows:

1. Input the Pixel values to the DWT and obtain the DWT output Values.
2. The same output values from the DWT are applied as input to the IDWT
3. Obtain the output values from the IDWT
4. Compare the values of both DWT input values and IDWT output Values, both Must be same.

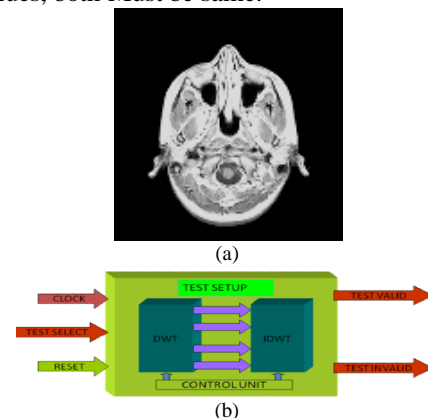


Figure 17. (a) Original Image. (b) Hardware Design Test setup

Matlab is used to obtain the pixel values for the Original image shown in fig-17 (a). The size of the image is found to be of 128x128 pixels. A set of 4x4 pixels of the Original image shown in fig-17(a) were given as test inputs. The test is implemented using the hardware design test setup shown in fig-17(b). The original image input pixels, lifting based DWT outputs/ IDWT inputs and IDWT outputs are as shown in Table-I

TABLE I. TEST RESULTS OF LIFTING BASED DWT AND IDWT

Original Pixel Input	DWT Output/IDWT Input	IDWT Output
0, 0, 0, 0,	-65, 503, 332, 0,	0, 0, 0, 0,
0, 0, 0, 190,	-95, 30, 283, 48,	0, 0, 0, 190,
0, 44, 218, 218,	223, 289, -83, -102,	0, 44, 218, 218,
86, 218, 218, 200.	0, 223, 66, -84.	86, 218, 218, 200.

Referring to Table I, it can be seen that, the original pixels values at the input of DWT and the pixel values at the output of IDWT are same. Using IDWT output values, the original image can be reconstructed. Fig-18 to Fig-23 shows the decomposition and reconstruction of images



Figure 18. Original image

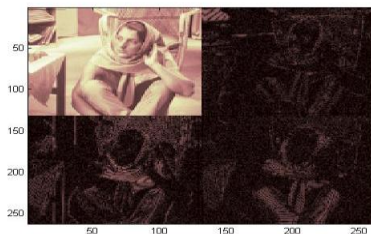


Figure 19. One level decomposing

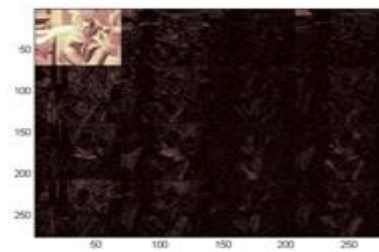


Figure 20. Two Level Decomposing



Figure 21. Reconstruction from Neural Network

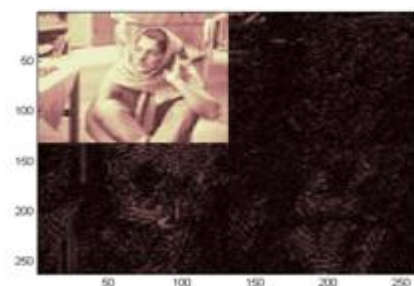


Figure 22. One Level Reconstruction

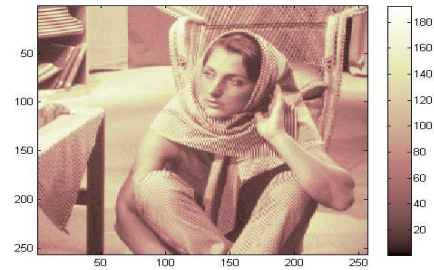


Figure 23. Final Reconstructed Image

IX. CONCLUSION

This paper provides fast-lifting based wavelet transform for image compression. The system converts the color image into grayscale image. The image is compressed. The image is compressed by 3 levels by using discrete wavelet transform and the compressed image is recovered by using inverse discrete wavelet transform. The original image is recovered. The peak signal to noise ratio is 55.62 and mean square error is 0.178. Number of coefficients recovered is 99.94%. Standard deviation is 2.537. Median absolute deviation is 0.943. Mean absolute deviation is 1.642.

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